NOTE *Surgery*

Quantitative Evaluation of Hip Joint Laxity in 22 Border Collies Using Computed Tomography

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ABSTRACT. The purpose of this study was to obtain the computed tomography (CT) data for the hip joints of 22 Border Collies. The dorsolateral subluxation (DLS) score, lateral center edge angle (LCEA), dorsal acetabular rim angle (DARA) and center distance (CD) index were measured on the CT images in a weight-bearing position. Radiographic Norberg angle (NA) was also measured. The mean values were 45.7 ± 10.2% for DLS score, 85.9° ± 10.3° for LCEA, 18.5° ± 7.3° for DARA, 0.40 ± 0.17 for CD index and 102.7°± 6.9° for NA. Since the DLS score and LCEA showed strong correlation, combined use of these parameters might improve diagnostic accuracy. We consider CT evaluation in a weight-bearing position to be a useful method for multidirectional evaluation of hips.

KEY WORDS: Border Collies, canine, CT, hip joint, weight-bearing position.

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The prevailing imaging methods for diagnosis of hip joint laxity and hip dysplasia include the Orthopedic Foundation for Animals (OFA) radiographic examination [13] and the radiographic distraction index (DI) [9]. Some studies have reported low diagnostic accuracy for the OFA examination. Although the DI technique has been reported to have high diagnostic accuracy and reproducibility, its use is limited due to the need for specialized equipment and technical training [9, 10]. The widespread use of computed tomography (CT) in veterinary medicine has made hip evaluation using CT a viable option in the ongoing effort to develop objective, versatile hip evaluation methods [2–4, 6, 14]. Objective evaluation requires loading of the hip in a manner similar to that achieved in a standing position rather than positioning the hip using an artificial and potentially variable traction force. CT evaluation with the hips in a weight-bearing position fulfills this requirement because the hip joints are loaded by the body weight of the lumbar area [3–5]. However, CT evaluation of hip joints still requires accumulation of CT data for various breeds in order to establish a methodology and criteria for each breed. In this study, 44 hips from 22 Border Collies—a breed that has not been studied in the past—were used to measure the dorsolateral subluxation score (DLS score), lateral center edge angle (LCEA), dorsal acetabular rim angle (DARA) and center distance index (CD index) from weight-bearing CT images. The radiographic Norberg angle (NA) was also measured in a standard ventrodorsal hip-extended radiographic projection. The mean values of all parameters were calculated and compared to the corresponding threshold values determined previously.

Twenty-two clinically healthy Border Collies (7 males and 15 females; 7–120 months; weight, 11.1–22.0 kg) raised on breeding farms were used in this investigation. Gait abnormalities and the Ortolani sign were absent in all dogs, and radiographic images revealed no evidence of osteoarthritis. Radiographic and CT procedures were performed with the subjects under general anesthesia. Anesthesia was induced with an intravenous injection of 4.0 mg/kg propofol (Rapinovet, Schering-Plough Animal Health, Tokyo, Japan) and was maintained with a continuous infusion of 20.0 mg/kg/hr propofol. All protocols were approved by the Institutional Animal Use and Care Administrative Advisory Committee. All CT images were acquired from the wing of the ilium to the ischial tuberosity using a multidetector-row CT (Asteion Super 4, Toshiba, Tokyo, Japan) with the following technical parameters: 0.5 mm slice thickness, 120 kVp, 150 mA, 1.0 sec/rotation, bone reconstruction algorithm and a 295 mm × 295 mm field-of-view. The dogs were placed in a weight-bearing position on the CT table according to Farese *et al.* [3]. The dogs were placed on a radiolucent styrofoam mold in sternal recumbency in a kneeling position to hold the femur perpendicular to the CT table. The stifles were flexed and in contact with the table. The mold had a simple structure and was large enough for the dogs to be placed on; it had an opening that enabled the stifles to come into contact with the table. Placement of a dog on the mold results in dorsolateral distraction of its hips from the weight load of the lumbar area on the hip joints. All planar radiographic images were obtained in the standard ventrodorsal hip extended projection using a standard clinical computed radiography system (Fujifilm, Tokyo, Japan).

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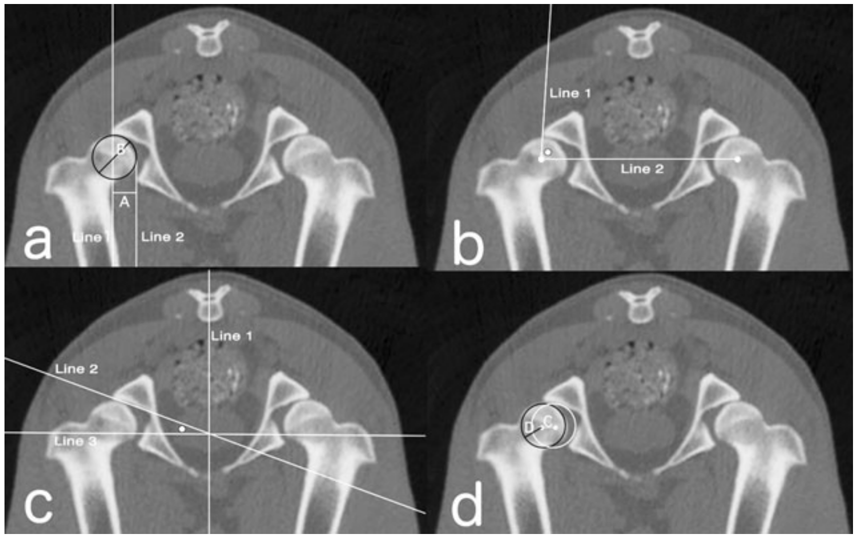

Fig. 1a. The DLS score was determined by measuring the distance between line 1 and line 2 (A) and dividing the distance by the widest diameter of the femoral head (B) using the equation DLS score=A/B × 100%. Line 1 passes through the most lateral point of the acetabular rim. Line 2 passes through the most medial edge of the femoral head. Line 1 and 2 are both perpendicular to a line connecting the most lateral points of the left and the right acetabular rim.

Fig. 1b. The LCEA was defined as the angle between line 1 and line 2. Line 1 connects the most lateral point of the acetabular rim and the center point of the femoral head, and line 2 connects the center point of the left and right femoral heads. The LCEA is similar to the radiographic NA; however, the NA is determined by using the cranial acetabular rim on radiographic ventrodorsal images as a landmark, while the LCEA is determined by using the dorsal acetabular rim on transverse CT images as a landmark.

Fig. 1c. The DARA is defined as the angle between line 2 and line 3. Line 1 is a vertically oriented central pelvic line connecting the caudal vertebra and the pubic symphysis. Line 2 is tangential to the dorsal acetabular subchondral articular surface. Line 3 is drawn at a right angle to line 1 at the intersection of lines 1 and 2.

Fig. 1d. The CD index was determined by measuring the distance between the center point of the femoral head and the center point of the acetabular space (C) and by dividing this distance by the radius of the femoral head (D) using the equation CD index=C/D.

The DLS score, LCEA, DARA, and the CD index (defined in Fig.1) were calculated from using measurements from transverse CT images that included the largest femoral head diameter. The NA was measured from radiographic images of the 44 hips acquired in the standard ventrodorsal hip extended projection. The NA was defined by 2 straight lines originating from the center of the femoral head—the first tangential to the craniolateral rim of the acetabulum and the second connecting the centers of the contralateral femoral heads [1]. CT parameters were measured using an image processing workstation (Virtual Place Advance, AZE, Tokyo, Japan), and the radiographic NA was measured using an image processing software (Image J; National Institutes of Health, Bethesda, MD, U.S.A.). The mean and standard deviation values of the DLS score, LCEA, DARA, CD index and NA were calculated for all 44 hips. In addition, the mean values for the DLS score, LCEA, DARA, CD index and NA were recalculated for the hips for which the parameters were ascertained to be within the reference range from previously published data. For the current investigation, the reference ranges were defined as follows: DLS score > 55% [3], LCEA > 94.2° [4], DARA < 15° [8], CD index < 0.22 [4] and NA >105° [12]. The correlations between the CT parameters were examined as were the correlations between the CT parameters and NA. In addition, correlations between age, body weight, CT parameters and NA were investigated. All correlations were analyzed using Spearman rank correlation.

The mean values of the parameters of the 44 hips of the 22 Border Collies were 45.7 ± 10.2% for DLS score, 85.9° ± 10.3° for LCEA, 18.5° ± 7.3° for DARA, 0.40 ± 0.17 for CD index and 102.7° ± 6.9° for NA.as follows: DLS score, 45.7% ± 10.2%; LCEA, 85.9° ± 10.3°; DARA, 18.5° ± 7.3°; CD index, 0.40 ± 0.17; and NA, 102.7° ± 6.9°. Table 1 shows the mean values of the DLS score, LCEA, DARA, CD index, and NA for the hips ascertained to be within the reference values ranges for each of these parameters. In the hips within the DLS score reference range (8 hips), the values of LCEA and DARA were within those of reference their reference ranges. In the hips within the LCEA reference range value (9 hips), the DLS score and DARA values were within their reference range. In the hips within the DARA reference range (14 hips), only the LCEA value was within its reference range. In the hips within the CD index

Table 1. Mean values of the DLS score, LCEA, DARA, CD index and NA for hip joints within the reference ranges

Hips within the reference ranges from past reports	Recalculatted mean values				
	DLS score (%)	LCEA (°)	DARA (°)	CD index	NA (°)
Within DLS score reference range (8 hips)		97.0 ± 2.3 a)	10.9 ± 2.3 a)	0.24 ± 0.04	104.8 ± 6.8
Within LCEA reference range (9 hips)	57.4 ± 2.4 a)		11.9 ± 3.8 a)	0.25 ± 0.06	103.8 ± 6.4
Within DARA reference range (14 hips)	54.3 ± 5.3	94.5 ± 3.8 a)		0.29 ± 0.07	104.7 ± 5.9
Within CD index reference range (5 hips)	53.8 ± 5.8	93.2 ± 5.1	12.5 ± 5.3 a)		99.6 ± 4.2
Within NA reference range (16 hips)	47.1 ± 8.3	87.7 ± 8.2	17.0 ± 4.9	0.40 ± 0.14	

a) Within the reference range of each parameters (DLS score>55%, LCEA>94.2°, DARA>15°, CD index < 0.22 and NA > 105°).

reference range (5 hips), only the DARA value was within its reference range. In the hips within the NA reference range (16 hips), none of the CT parameters were within their reference range. With regard to the correlation among the CT parameters (n=44), the DLS score and LCEA showed very strong correlation (r=0.978, p<0.01). There were strong correlations between the DLS score and CD index (r=0.837, p<0.01), LCEA and CD index (r=0.813, p<0.01), LCEA and DARA (r=0.765, p<0.01), and DLS score and DARA (r=0.748, p<0.01). Moderate correlation was observed between DARA and the CD index (r=0.656, p<0.01). Although there were weak correlations between LCEA and NA (r=0.338, p<0.05) and between DARA and NA (r=0.300, p<0.05), there were no correlations between the DLS score and NA or between the CD index and NA. In addition, weak correlations were observed between body weight and the DLS score (r=0.317, p<0.05), body weight and LCEA (r=0.316, p<0.05) and between age and the CD index (r= –0.325, p<0.05).

In the present study, the mean values of the DLS score, LCEA, DARA, CD index, and NA were calculated for 22 Border Collies, which is a breed that has not been widely studied. The mean values of all the parameters measured for the 44 hips deviated from the previously established reference values. One of the reasons for this might be the relatively wide range of the ages and body weights of the dogs used in this study. The Ortolani sign and gait abnormalities were not observed in any of the dogs; however, other potential factors may have been present, such as abrasion of the femoral head with advancing age or increaseding body weight. In addition, a previous study has indicated the need for a validation study using various breeds to validate the NA reference value range [1]. Therefore, the reference ranges value of the CT parameters should also be determined for each dog breed. The recalculated LCEA and DARA were within reference ranges in hips with a DLS score within the reference range from past reports. The recalculated DLS score and DARA were within the reference ranges in hips that showed LCEA values within the reference range from past reports. Only the recalculated LCEA values were within the reference range in the hips within the DARA reference range from past reports. And only the recalculated DARA values were within the reference range in the hips within the CD index reference range from past reports. None of the recalculated parameters were within the reference range in the hips within the NA reference range from past reports. Since the DLS score and LCEA showed a strong correlation, a high diagnostic accuracy for hip laxity might be achieved by considering both the distance (DLS score) and angle (LCEA) between the acetabulum and the femoral head instead of considering these parameters individually [11]. The correlation between the DLS score and body weight and between LCEA and body weight, however weak, implies the possibility of the influence of body weight on hip laxity [7]. In the present study, moderate correlation was observed between all the CT parameters; however, weak or no correlation was observed between the CT parameters and NA. Moreover, the mean values of the CT parameters of the hips within the NA reference range (16 hips) deviated from the reference range of the DLS score, LCEA, DARA, and CD index. The possible reasons for this include the difference in the directions of loading on the hip joints between the NA and CT parameters and the possibility of definition of an overly stringent threshold defined for the NA reference range (over 105°) [9]. However, the diagnostic accuracy of the LCEA, the determination of which is similar to that of NA, was correlated with many parameters other than NA. This may be due to the lack of adequate loading on the hip joints in the standard ventrodorsal hip extended projection.

Hip evaluation in a weight-bearing position by using CT is a method that involves no application of artificial traction forces on the hips during the scanning. Loading of the animals own body weight onto the hips may be more relevant than loading in a simple prone or supine recumbent position [4]. In addition, the influence of degeneration or laxity of the hip joints on clinical signs can be inferred by loading with the animal's own body weight without any forced traction or loading. Furthermore, CT evaluation requires no special procedures regarding positioning of the animal for image acquisition, and the quantitative image analysis can be performed easily on a workstation with a high degree of accuracy. Border Collies were used in the present study; however, this breed is not frequently affected by degenerative joint disease or hip dysplasia. With regard to hip dysplasia, the incidence rate is 11.1% (middle rank among all breeds) according to OFA statistics. However, unlike the Greyhound, the Border Collie is not normally considered a "low-incidence breed"; this is because the percentage of excellent hip joints is relatively low (11.9%). In addition, the Border Collie is not only a pet but is also a herding or disc dog. Thus, it is possible that an increase in population would result in an increased incidence of hip joint problems. Therefore, the hip joint data obtained in the present study using Border Collies, a breed for which data has not previously been reported, can surely contribute to the study of quantitative evaluation of hip joints for different breeds. In conclusion, we consider CT evaluation in a weight-bearing position to be a useful evaluation method for hip laxity as well as for multidirectional evaluation of hips. Furthermore, it could serve as an adjunct or alternative to radiographic distraction index and OFA evaluation. Future studies are needed to not only accumulate abundant data of concerning hip laxity and degenerated joint disease but also to validate the possibility of using CT evaluation as a method to determine the predictive indicators of hip dysplasia in immature hip joints.

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